Language-independent working memory as measured by Japanese and English reading span tests

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The efficiency of working memory capacity was measured with the use of a reading span test (RST) written in Japanese and in English. The Japanese version of the RST was based on the RST developed by Daneman and Carpenter (1980) in English (CMU version). An English-as-a-second-language version (ESL version) was also developed for native Japanese college students. The correlation between the Japanese and ESL versions was found to be highly significant (0.84). Moreover, the correlation between the Japanese and CMU versions was found to be high (0.72). The results indicate that the efficiency of working memory for reading appears to be independent of language structure. Thus, the presently developed Japanese version of the RST is likely to predict reading efficiency in the same way that the CMU version does.

Working memory represents the immediate memory processes involved in the simultaneous storage and processing of information (Baddeley, 1986; Carpenter & Just, 1989). In working memory, the emphasis is on the efficiency of storing the partial product of comprehension for a limited period while incoming information is being processed (Carpenter & Just, 1989). Relative efficiency in such processing can be expressed in terms of working memory capacity (Carpenter & Just, 1989).

In order to measure working memory capacity, Daneman and Carpenter (1980) developed a reading span test (RST). The RST is a memory test designed to measure both processing and storage functions during reading. This test can measure the working memory capacity that is closely related to an individual's reading ability. Working memory is thought to play an important role in comprehension processes that occur during reading. In reading, incoming information is decoded perceptually, reorganized, and integrated with the ongoing textual interpretation through the use of syntactic, pragmatic, and semantic information while the products of these processes are being stored for a short period (Daneman & Carpenter, 1980; Kintsch & van Dijk, 1978). In this way, the information

from the text must be stored so that it can be referred to at any time. The reader who happens to encounter an ambiguous word can thus utilize the information that precedes the sentence. The storing and processing are managed in a parallel manner. Good readers are assumed to be efficient in reading the text; they need not waste the capacity allocated for processing the information, and they can store the products of the processes readily. In the RST, the excellent reader has more working memory capacity to store information during text reading. Daneman and Carpenter (1980) also suggest that the reading span score shows significant correlation with reading comprehension scores. Moreover, it has also been suggested that performance on the RST reflects individual differences in language comprehension (Daneman & Green, 1986).

In most research, the RST has been in the subject's native language rather than a second language. If, however, the working memory capacity is not language dependent, RST scores should show a correlation with scores for the second language as well. If one has sufficient comprehension in the second language, one will have a similar efficiency in processing the second language. The purpose of the present investigation was to examine the relationships between working memory capacity in the first and second languages. We compared reading spans for Japanese and for English among Japanese students who had studied English for more than 6 years.

METHOD

Subjects

The subjects were 30 undergraduate students from the Osaka University of Foreign Studies. They were all native Japanese speakers who had

studied English for 7-9 years. Since they came from the English Department, which requires an extensive proficiency in English, their English skills may be considered to have been at or near the bilingual level.

Materials

Eighty Japanese sentences were selected from a high school textbook. The lengths of the sentences ranged from 20 to 28 characters. The length was measured in terms of character units because of the properties of Japanese orthography (see Osaka, 1989, for details). The kanji contribution factor of each sentence was approximately 0.3 (Osaka, 1989), and familiarity with each kanji word was controlled.

English sentences were also selected from textbooks used in high school, according to the same criteria as those for the Japanese sentence selection. The lengths of the sentences ranged from 9 to 13 words.

Prior to the experiment, the difficulty level was rated by 40 native Japanese students who did not participate in the RST session. A 7-point rating scale (1 for *easiest* and 7 for *most difficult*) was used. The rated values of the Japanese and English sentences ranged from 2.20 to 5.12 and from 0.75 to 3.75, respectively. To keep the difficulty level equal, 10 sentences were discarded from both the Japanese and the English texts.

Procedure

English reading span test (ESL version). The procedure for this test was almost the same as that of Daneman and Carpenter (1980). Each sentence was printed on a single line across the center of a 13×18 cm white card. The cards were arranged in five sets, each of which comprised two, three, four, and five sentences. Blank cards were inserted between the sets. Within a set, the sentences were not related to each other. The subject was asked to read each sentence aloud at his/her own pace. As soon as the subject finished reading a sentence orally, the next sentence was presented and the subject was forced to continue reading aloud. After reading all the sentences in a set, the subject was asked to recall the last word of each sentence within the set. The order of reporting these final words was based on the free recall procedure. The subject was prohibited from reporting the last target word first within each set, in order to avoid the recency effect.

Japanese reading span test (Japanese version). The Japanese RST was almost the same as the ESL version, except that the word to be reported was underlined in red. Therefore, the target word was located not only at the end of a sentence, but also at any position within a sentence. The position of the target word was randomized. Moreover, the target could be a noun, verb, or adjective, and some were written in kanji, in hirakana, or in mixed characters.

Daneman and Carpenter reading span test (CMU version). Daneman and Carpenter originally developed the RST at Carnegie-Mellon University in 1980. This version contains a series of up to five sets in each reading span measure.

The subjects were presented with increasingly longer sets of sentences until they failed four sets at a particular level. The level at which a subject correctly answered three out of five sets was taken as a measure of the subject's reading span. If the subject was correct on only two out of the five sets at a particular level, the subject was given a credit of 0.5. The order of the sessions for Japanese, ESL, and CMU was randomized.

RESULTS AND DISCUSSION

Figure 1 shows the correlation between the Japanese and ESL versions of the RST. Figure 2 shows the correlation between the Japanese and CMU versions of RST. The line in each figure shows the least squares fit. Both figures showed high correlations between Japanese and English. Comparison of Figures 1 and 2 indicates that the overall ESL score was relatively higher than the overall CMU score, especially for midrange readers who scored between 3.0 to 4.0. This may have been due to the subjects' higher familiarity with the English vocabulary items on the ESL test. Note that most of the highest scoring group (scores from 4.5 to 5.0) tended to maintain high
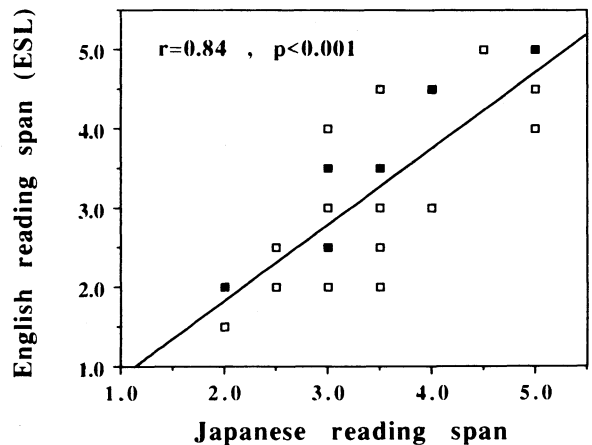

Figure 1. Correlation between Japanese and ESL version RST scores. Filled squares show the same scores measured more than two times ($n = 30$).
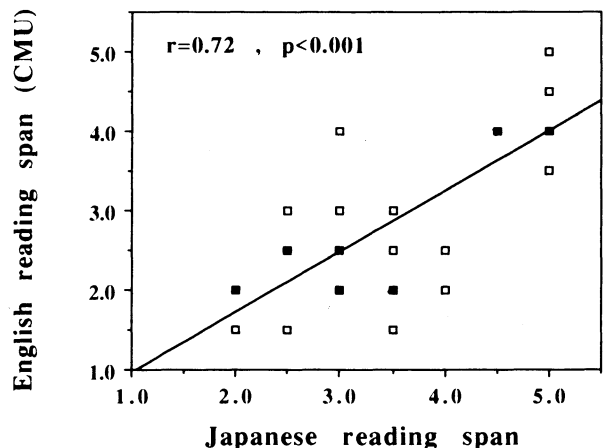

Figure 2. Correlation between Japanese and CMU version RST scores. Filled squares show the same scores measured more than two times ($n = 30$).

scores regardless of differences in vocabulary and expression between the ESL and the CMU. It appears that the higher the span, the more language independent the reader tended to be. Thus, the working memory efficiency revealed by RST is, in general, language independent. Figure 3 shows the correlation between the ESL and CMU versions of the RST. These data also confirm the higher correlation between the ESL and the CMU, which was predicted previously.

Table 1 shows Pearson's correlation coefficients for the Japanese, ESL, and CMU scores from 30 subjects. Reading span scores on the Japanese version varied from 2.0 to 5.0, with a mean of 3.45 ($SD = 0.97$), and on the English version, from 1.5 to 5.0 with a mean of 3.23 ($SD = 1.10$). The scores for the CMU version varied from 1.5 to 5.0, with a mean of 2.88 ($SD = 1.0$). The Japanese reading spans are very close to the results of
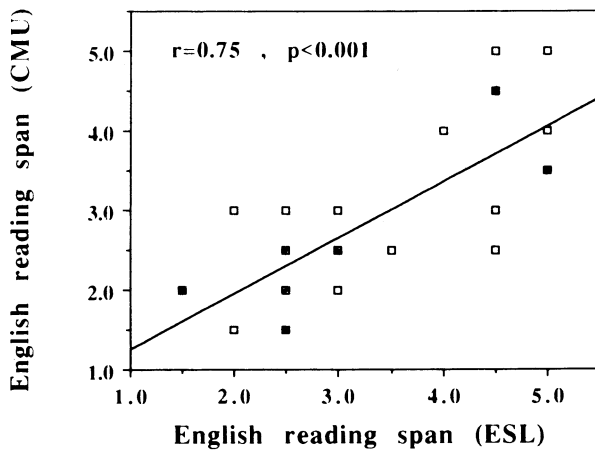
Figure 3. Correlation between ESL and CMU version RST scores. Filled squares show the same scores measured more than two times (*n* = 30).

Table 1
Correlations Among Japanese, English ESL, and English CMU Reading Span Scores

Reading Span Test	Reading Span Test		
	Japanese	ESL	CMU
Japanese	–		
ESL	0.84*	–	
CMU	0.72*	0.75*	–

Note—*n* = 30.   **p* < .001.

Daneman & Carpenter (1980), who reported, using 20 subjects, that the reading span varied from 2 to 5 with the mean of 3.15 (*SD* = 0.93). This is quite similar to the results in the present study. Moreover, the Japanese students had similar scores on both the ESL and the Japanese versions. The correlation coefficients between Japanese-ESL, Japanese-CMU, and ESL-CMU were 0.84, 0.72, and 0.75, respectively. All of these coefficients were statistically significant (*ps* < .001). The results show that the working memory capacity related to language processing is stable, as predicted. If a student has a high reading span in his or her native language, the student will be able to develop a high reading span in a second language as well. However, if a student has a lower reading span in the native language, the student will not be able to develop a high span, as measured by the second language RST. After finishing the session, the high-span readers verbally reported that they tried to visualize the sentences and then chunked the target words into storage. This suggests that the high-span reader has a larger capacity to work with strategic memorization. In summary, the efficiency of working memory capacity during reading is language independent.

REFERENCES

BADDELEY, A. D. (1986). *Working memory*. New York: Oxford University Press.

CARPENTER, P. A., & JUST, M. A. (1989). The role of working memory in language comprehension. In D. Klahr & K. Kotovsky (Eds.), *Complex information processing: The impact of Herbert Simon* (pp. 31-68). Hillsdale, NJ: Erlbaum.

DANEMAN, M., & CARPENTER, P. A. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning & Verbal Behavior*, **19**, 450-466.

DANEMAN, M., & GREEN, I. (1986). Individual differences in comprehending and producing words in context. *Journal of Memory & Language*, **25**, 1-18.

KINTSCH, W., & VAN DIJK, T. A. (1978). Toward a model of text comprehension and production. *Psychological Review*, **85**, 363-394.

OSAKA, N. (1989). Eye fixation and saccade during kana and kanji text reading: Comparison of English and Japanese text processing. *Bulletin of the Psychonomic Society*, **27**, 548-550.

OSAKA, N. (1990). Spread of visual attention during fixation while reading Japanese text. In R. Groner, G. d'Ydewalle, & R. Parham (Eds.), *From eye to mind: Information acquisition in perception, search, and reading* (pp. 167-178). Amsterdam: North Holland.